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2D Microwave Imaging of the Breast Tissue: Forward Problem Technique

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***Abstract*— *Microwave imaging is the method that used to detect breast cancer. Previous research is done by inverse problem and forward problem solution, but the inverse problem is difficult to solve because there are many unknown constants. Thus in this paper, microwave imaging is solved by different way, i.e. using forward problem solution only with the aim to easier the imaging process without ignoring the resolution. So the malignant breast cancer is easier to detect and this technique can be used as an easy, safe, and cheap of early detection of the breast cancer. This process is done by illuminating normal and malignant breast tissue model using microwave at frequencies 5GHz, 10GHz, and 15GHz. Then the scattered field data are calculated by Method of Moment. The scattered field data is presented in 2D figure. The results show that normal and malignant breast tissue produce different scattered field patterns. The normal breast tissue tends to produce more curve pattern around object. This difference in patterns can be used as a reference to distinguish between normal and malignant breast tissue.*

***Keywords*— Dielectric Constant, Forward Problem, Method of Moment, Microwave Imaging.**

I. INTRODUCTION

Breast cancer is the most often cancer that affects women and causes many deaths. Early detection can improve treatment succes and safe patient from the deaths. Microwave imaging is the imaging method that has been developed for early detection of breast cancer, because microwave imaging do not ionize the breast tissue, lower cost, and do not use compression [1], [2].

Previous research about microwave imaging have been done by using Microwave Tomography (MWT) [3]–[5]. Microwave tomography technique consists of two process, inverse problem solution and forward problem solution. Forward problem solution calculates scattered field around breast object using Maxwell equation. While inverse problem estimates dielectric properties of the breast tissue from the measurable scattered field data produced by forward problem [6]. However the researchs about MWT technique do not develop faster[4], [7]. This is because the large dielectric contrast of biologist tissue so that generates the change of inverse problem solution, that is the appearance of complex permittivity function in the Maxwell equation thus becoming non linear equation [8]. Because there are many unknown constants, the inverse problem solution becomes more complicated [9], needs more time [10], and needs adquate computer [4]. Whereas the inverse problem solution is needed to produce accurate solution.

To solve this problem, we present the alternating solution of microwave imaging. i.e microwave imaging based on the scattering image that produced by forward problem solution. This microwave imaging technique is simpler than previous technique, because only using forward problem solution. Therefore the resulting images can not show the component that exist in the breast tissue, but only the scattered field around the breast object. Nevertheles, the result of forward problem solution still can be used to detect cancer in the breast tissue. This is due to the dielectric constant of the breast. The dielectric constant of the normal breast tissue and malignant breast tissue is different [10]–[12]. Malignant breast tissue has greater dielectric constant than normal breast tissue because malignant breast tissue contains more water [13]. The difference in the dielectric constant causes a difference in scattering patterns. The pattern of the scattered field can be used as a reference to distinguish between normal breast tissue and malignant breast tissue. So the microwave imaging with forward problem solution can be used as early detection method.

II. METHOD

In this section we describe tomography model, object model, and mathematical model. The tomography model used is shown in Fig. 1. We can see that antennas are located around object. Each antenna can swich as a transmitter or receiver antennas. If the first antenna as a transmitter antenna so the other antennas as a receiver antenna, this happens until the last antenna. The transmitter antenna illuminates object using microwave

with frequencies 3 GHz, 9 GHz, and 15 GHz alternately and the scattered fields are observed at receiver antennas.

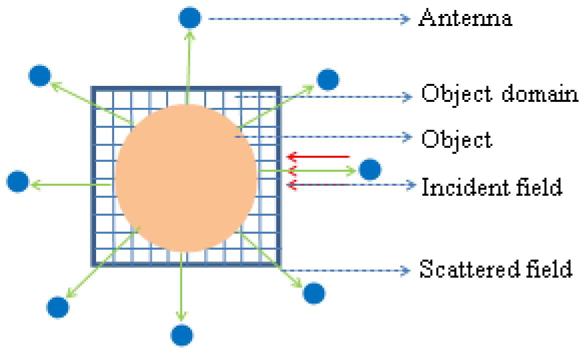

Fig.1: Tomography Model

Breast object is modeled by dielectric silinder with radius 3 cm. There are two objects, normal breast object and malignant breast object. Both of them are modeled by Cole-cole equation.

$$\varepsilon(\omega) = \varepsilon_\infty + \frac{\Delta\varepsilon}{1+(j\omega\tau)^{1-\alpha}} + \frac{\sigma}{j\omega\varepsilon_0} \qquad (1)$$

$\varepsilon(\omega)$ is the dielectric constant that changed depend on angular frequency, ε_0 is relative dielectric constant of material, ε_∞ is infinite dielectric constant, $\Delta\varepsilon$ is the reduction between static dielectric constant and infinite dielectric constant $(\varepsilon_s - \varepsilon_\infty)$, α is expontial parameter, ω is angular frequency, τ is time constant, and σ is material conductivity. The Cole-cole parameters are shown in the Table 1.

Table 1. Cole-cole parameters [14]

Parameter	Normal	Malignant
ε_∞	3.00	8.00
$\Delta\varepsilon$	1.00	50.50
α	0.10	0.04
τ	20.00	10.50
σ	0.036	0.90

The mathematical model states the breast object model and electrical field in the mathematical equation. The imaging process can be stated in three equation, scattered field, incident field, and total field.

$$E^i(\vec{r}) = E^t(\vec{r}) - E^s(\vec{r}) \qquad (2)$$

By using vector potential, Green function, and polarization current density principle, the equation 1 can be stated as

$$E^i(\vec{r}) = \frac{1}{jw(\varepsilon-\varepsilon_0)} J(r) - jk_0\eta_0 \iint_\Omega \frac{1}{4j} J(r') H_0^2(k_0\rho)\, dr' \qquad (3)$$

The polarization current density in equation 3 is unknown, so the value must be determined first before determines the scattered field. Therefore we use Method of Moment (MoM) to solve this forward problem. MoM is more efficient that other numerical method, because MoM use Green function so the boundary condition can be fulfilled automatically [15]. By applying pulse basic function, the breast object is divided into N cell that have same size. So the polarization current density at each cell can be stated as

$$J(r) = \sum_{n'=1}^{N} J_{n'} P_{n'} \qquad (4)$$

Where pulse basic function is

$$\begin{aligned} p_n &= 1 \rightarrow ((r) \in cell_n) \\ p_n &= 0 \rightarrow (elsewhere) \end{aligned} \qquad (5)$$

By subtituting equation 4 into equation 3, we can states

$$[E_n^i] = [Z_{nn'}][J_{n'}] \qquad (6)$$

Where

$$\begin{aligned} [Z_{nn'}] &= \frac{\eta_0 \pi a_n}{2} J_1(k_0 a) H_0^{(2)}(k_0\rho) \rightarrow \rho > a(n \neq n') \\ [Z_{nn'}] &= \frac{\eta_0 \pi a_n}{2} H_1^{(2)}(k_0 a) \rightarrow \rho \leq a(n = n') \end{aligned} \qquad (7)$$

Thus the polarization current density can be calculated. Based on the equation 3, the scattered field can be stated in

$$E^s(r) = jk_0\eta_0 \iint_\Omega \frac{1}{4j} J(r') H_0^{(2)}(k_0\rho)\, dr' \qquad (8)$$

By subtituting equation the polarization current density to equation 8, the scattered field produced by each cell and each projection can be approximated as

$$[E_m^s]_t = [Z_{nn'}][J_{n'}]_t \qquad (9)$$

Thus the scattered field around breast object can be calculated and presented in 2D images.

III. RESULTS AND DISCUSSION

The scattered data around breast object is presented in 2D image. Where the magnitude of the scattered field is shown by color as seen in the legend besides. The dark red color shows the greatest magnitude of scattered field and the dark blue shows the smallest magnitude of scattered field. The results are shown in Fig. 2. If seen in general, the area that located at opposite transmitter has greater magnitude of scattered field than other area. This applies to normal and malignant breast tissue at frequencies 5GHz, 10GHz, and 15GHz. However, both of them has different scattered field patterns. At 5GHz, the different pattern between normal and malignant breast tissue is not so visible. But still there is a different pattern at area located in same side with transmitter antenna, where the malignant breast tissue has greater magnitude of scattered field than normal breast tissue as seen in

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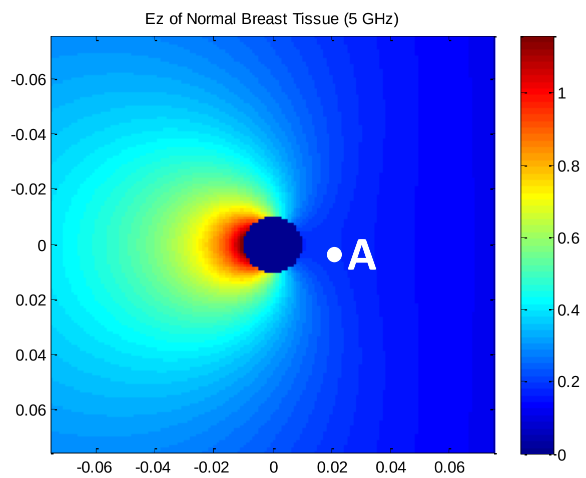
point A, where the normal breast tissue is shown by blue color and malignant breast tissue is shown by light blue color that forming a curve pattern.

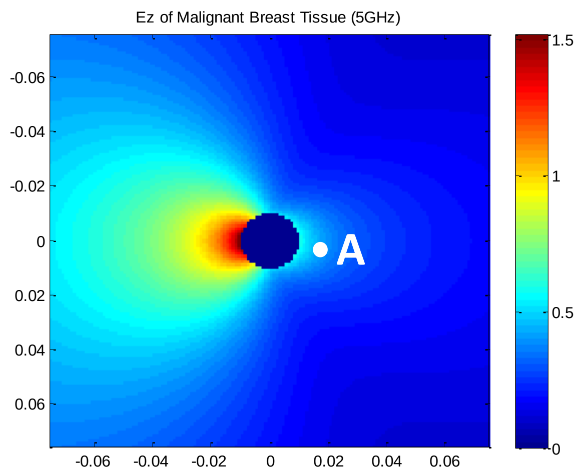
At 10GHz the different pattern is clearly visible. Normal breast tissue produces four curve pattern around the normal breast tissue which resembles dark and bright patterns. But only curve pattern that located at opposite transmitter antenna has greatest magnitude of scattered field. While malignant breast tissue produce one elongated pattern at the area opposite the transmitter antenna and one curve pattern at the same side area with transmitter antenna. If seen in point B, we can see that normal breast tissue is shown in blue color, while the malignant breast tissue is shown in green color. This shows that malignant breast tissue produces greater magnitude of scattered field than normal breast tissue.

The different pattern of scattered field at 15GHz also clearly visible. Both of them has similar pattern with scattered field pattern at 10 GHz, but more complex. Normal breast cancer produce six curve pattern around breast object. While malignant breast tissue produce one oval pattern and two small curve pattern. Same with the image at 5GHz and 10 GHz before, malignant breast tissue also produces greater magnitude as seen in point C which is shown in light blue color. This results show that normal breast tissue tends to produce curve pattern around breast object and has smaller magnitude of scattered field than malignant breast tissue. The different pattern between normal and malignant is better observed at 10GHz and 15GHz. This result is due to the difraction process in the breast tissue. Which the cells in the breast tissue are considered as narrow slit. So when the microwave illuminates the breast tissue, the microwave is deflected and become the scattered field. When the frequency used is suitable with the slit, so the dark and bright pattern are produced. Thus the normal breast tissue at 10GHz and 15 GHz produce dark and bright pattern, while the malignant breast tissue does not.

The difference in dielectric constant causes a difference in scattering patterns. Malignant breast tissue has greater dielectric constant than normal breast tissue. When illuminated using microwave, the centroid of the positive and negative charge which is bound will shift from its initial position. Thus the atom are polarized with dipole moment and produces polarization current in the breast tissue. The polarization current density is influenced by dielectric constant and frequency of microwave. Thus the tissue with greater dielectric constant produces more polarization current density. The presence of the polarization current density in a dielectric tissue causes scattered field around it. The greater polarization current density the greater magnitude of scattered field produced. Suitable with equation 8, polarization current density is directly proportional with scattered field. Therefore the scattered field produced by malignant breast tissue has greater magnitude than normal breast tissue.

At different frequency of microwave, the pattern of scattered field is different, both normal and malignant breast tissue. The scattered field at 15 GHz has more complex pattern than scattered field at 10 GHz and 5 GHz. However, the magnitude of scattered field is smaller. It can be seen from the pattern of scattered field at opposite area with transmitter, which is shrinking more when the higher frequencies of microwave used (indicated by color around object). This is because frequency influences the dielectric constant of the breast tissue. Suitable with Cole-cole equation, the greater frequency used the smaller dielectric constant of the breast. So magnitude of the scattered field decreases.This is suitable with previous research by Winters *et al.* (2006).





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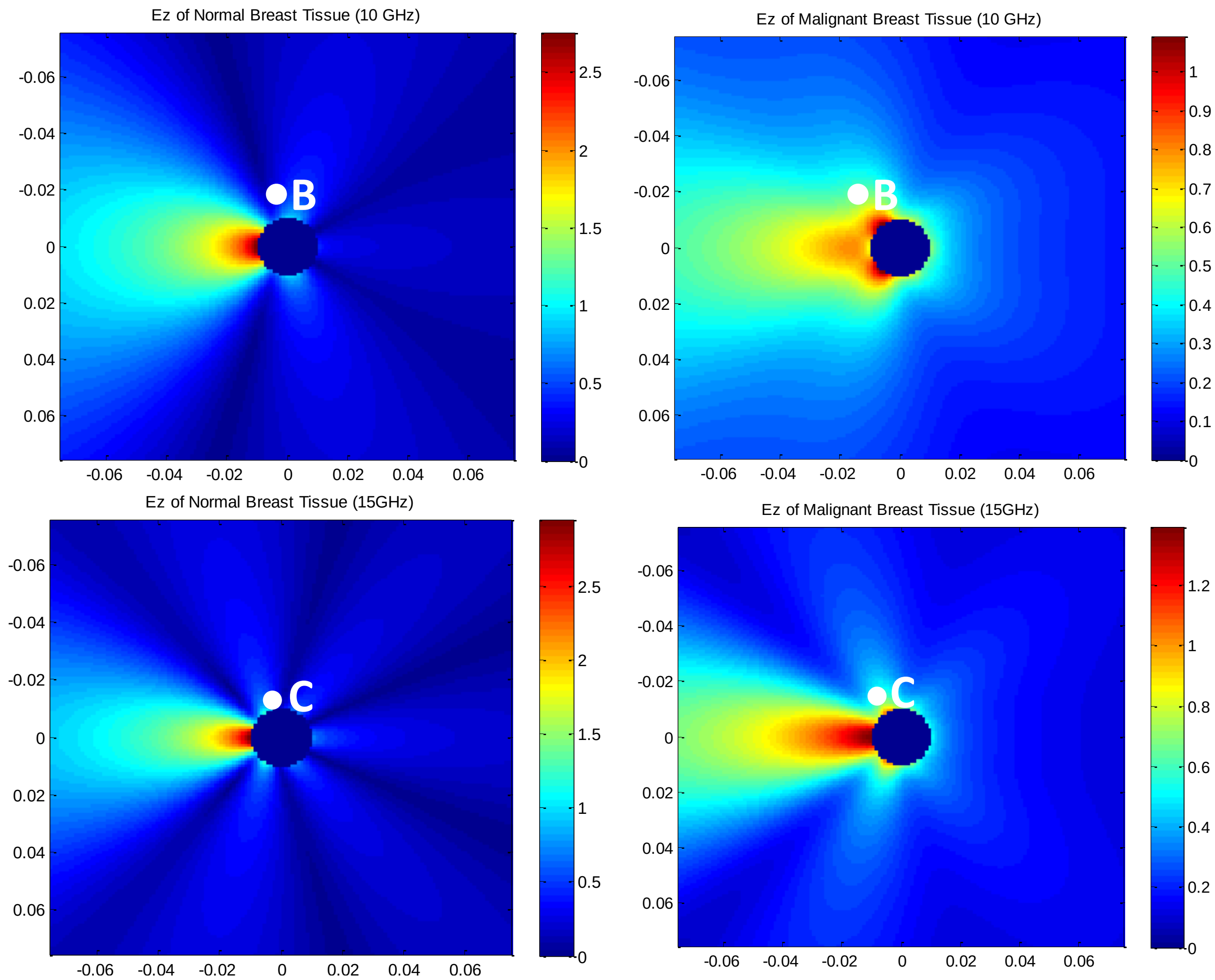

Fig. 2: Scattered field of normal and malignant breast tissue at 5GHz, 10GHz, and 15GHz

IV. CONCLUSION

We have been shown the microwave imaging using forward problem solution and MoM. Based on the result, we can see that the normal and malignant breast tissue produce different scattering patterns. Normal breast tissue tends to produces many curve patterns around the object and have smaller magnitude than malignant breast tissue. At 15 GHz, the difference of scattering patterns is seen clearly, so this frequency can be an effective frequency for breast imaging. Nevertheles this numerical algorithm can not be used to determine the position of tumor in the breast tissue, but this algorithm already can be used as an early detection of breast cancer, because this algorithm can distinguish between the pattern that produced by normal and malignant breast tissue. The further research can be done by considering the higher frequencies of microwave to know the most effective frequency to detect breast cancer.

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